

## SOLAR RADIATION AND EXPOSURE TO SUNLAMPS OR SUNBEDS

First listed in the *Ninth Report on Carcinogens*\*

### CARCINOGENICITY

Solar radiation is *known to be a human carcinogen*, based on sufficient evidence of carcinogenicity from studies in humans, which indicate a causal relationship between exposure to solar radiation and cutaneous malignant melanoma and non-melanocytic skin cancer. Some studies suggest that solar radiation may also be associated with melanoma of the eye and non-Hodgkin's lymphoma (reviewed in IARC V.55, 1992).

Exposure to sunlamps or sunbeds is *known to be a human carcinogen*, based on sufficient evidence of carcinogenicity from studies in humans, which indicate a causal relationship between exposure to sunlamps or sunbeds and human cancer. Epidemiological studies have shown that exposure to sunlamps or sunbeds is associated with cutaneous malignant melanoma (Swerdlow et al., 1988; Walter et al., 1990; Autier et al., 1994; Westerdahl et al., 1994). Exposure-response relationships were observed for increasing duration of exposure, and effects were especially pronounced in individuals under 30 and those who experienced sunburn. Malignant melanoma of the eye is also associated with use of sunlamps. In contrast, there is little support for an association of exposure to sunlamps or sunbeds with non-melanocytic skin cancer (IARC V.55, 1992).

The evidence that solar radiation and exposure to sunlamps or sunbeds are human carcinogens is supported by experimental studies in laboratory animals, and studies demonstrating UV-induced DNA damage in human and animal cells. Sunlamps and sunbeds emit radiation primarily in the ultraviolet A (UVA) and ultraviolet B (UVB) portion of the spectrum. Numerous studies have shown that simulated solar radiation, broad spectrum UV radiation, UVA radiation, UVB radiation, and UVC radiation are carcinogenic in experimental animals. There is evidence for benign and malignant skin tumors and for tumors of the cornea and conjunctiva in mice, rats, and hamsters. UV radiation also causes a wide spectrum of DNA damage resulting in mutations and other genetic alterations in a variety of *in vitro* and *in vivo* assays for genotoxicity, including assays using human skin cells (IARC V.55, 1992).

### PROPERTIES

Solar radiation from the sun includes most of the electromagnetic spectrum (IARC V.55, 1992). Of the bands within the optical radiation spectrum, UV light is the most energetic and biologically damaging. UV light is divided into UVA, UVB, and UVC. UVA is the most abundant of the three, representing 95% of the solar UV energy to hit the equator, and UVB represents the other 5%. The short wavelength UVC rays are absorbed by ozone, molecular oxygen, and water vapor in the upper atmosphere so that measurable amounts from solar radiation do not reach the earth's surface (Farmer and Naylor, 1996).

Molecules that absorb UV and visible light contain moieties called chromophoric groups in which electrons are excited from the ground state to higher energy states. In returning to lower energy or ground states, the molecules generally re-emit light (Dyer, 1965). Molecules sensitive to UV light absorb and emit UV light at characteristic maximum wavelengths ( $\lambda$ ), often expressed as  $\lambda_{\text{max}}$ .

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There is no separate CAS registry number assigned to solar radiation and exposure to sunlamps or sunbeds.

Photochemical and photobiological interactions occur when photons of optical radiation react with a photoreactive molecule, resulting in either a photochemically altered molecule or two dissociated molecules (Phillips, 1983; Smith, 1989; both cited by IARC V.55, 1992). To alter molecules, a sufficient amount of energy is required to alter a photoreactive chemical bond (breaking the original bond and/or forming new bonds).

UVB is considered to be the major cause of skin cancer despite its not penetrating the skin as deeply as UVA or reacting with the epidermis as vigorously as UVC. UVB's reactivity with macromolecules combined with depth of penetration make it the biologically most potent portion of the UV spectrum, with respect to short-term and long-term effects. UVA, while possibly not as dangerous, also induces biological damage (Farmer and Naylor, 1996).

Photobiological reactions of concern for skin cancer risk due to UV light exposure are the reactions with the main chromophores of the epidermis—urocanic acid, DNA, tryptophan, tyrosine and the melanins. DNA photoproducts include pyrimidine dimers, pyrimidine-pyrimidone (6-4) photoproducts, thymine glycols, and DNA exhibiting cytosine and purine damage and other damage such as DNA strand breaks and cross-links and DNA-protein cross-links. The different DNA photoproducts have varying mutagenic potential (IARC V.55, 1992).

UV-induced DNA photoproducts produce a variety of cellular responses that contribute to skin cancer. Unrepaired DNA photoproducts may result in the release of cytokines that contribute to tumor promotion, tumor progression, immunosuppression, and the induction of latent viruses (Yarosh and Kripke, 1996; IARC V.55, 1992).

## **USE**

Aside from the many benefits of sunlight/solar radiation, artificial sources of UVR are used for cosmetic tanning, promotion of polymerization reactions, laboratory and medical diagnostic practices and phototherapy, and numerous other applications (IARC V.55, 1992).

## **SOURCES**

Ultraviolet light is naturally emitted by the sun and artificially from lamps such as tungsten-halogen lamps, gas discharge, arc, fluorescent, metal halide, and electrodeless lamps (IARC V.55, 1992) and lasers such as the 308-nm XeCl (xenon chloride) excimer and the 193-nm ArF (argon fluoride) excimer (Sternborg et al., 1991).

The use of sunlamps and tanning beds is as a cosmetic source. The latter chiefly emit UVA (315-400 nm) although certain lamps that emitted considerable UVB and UVC radiation were more common before the mid-1970s (IARC V.55, 1992). However, UVB produces a better tan than UVA and recently, at least in the United States and United Kingdom, use of sunlamps with more UVB radiation has become widespread (Wright et al., 1997; cited by Swerdlow and Weinstock, 1998). Low-pressure mercury vapor lamps, sunlamps, and black-light lamps are considered to be low-intensity UV sources. High-intensity UV sources include high-pressure mercury vapor lamps, high-pressure xenon arcs, xenon-mercury arcs, plasma torches, and welding arcs. Three different UVA phosphors have been used in sunlamps sold in the United States over the past 20 years, producing emission spectra that peak at 340 nm, 350 nm, or 366 nm. Two modern U.S. sunlamps evaluated by the FDA emitted 99.0% and 95.7% UVA and the rest UVB radiation (<320 nm). A new high-pressure UVA sunbed with eighteen 1600-W filtered arc lamps emitted 99.9% UVA. An older-type sunlamp used more than 20 years ago

(UVB/FS type) emitted 48.7% UVA (Miller et al., 1998).

## EXPOSURE

The greatest source of human exposure to UVR is solar radiation; however, the exposure varies with the geographical location. With decreasing latitude or increasing altitude, there is greater exposure; for every 1000 feet above sea level, a 4% compounded increase in UVR exists. Decreases in the stratospheric ozone caused by chemicals generating free radicals increase UVR exposure. Heat, wind, humidity, pollutants, cloud cover, snow, season, and the time of day also affect UVR exposure (Consensus Development Panel, 1991).

Although use of sunscreen is known to protect from skin damage induced by UVR, sunscreen use has not become habitual by a large fraction of the U.S. population. For example, Newman et al. (1996) surveyed a random sample of persons in San Diego, a location with one of the highest incidences of skin cancer in the United States. Sunscreen was used only about 50% of the time on both face and body by tanners, about 40% of the time on the face, and 30% of the time on the body.

Most bulbs sold in the United States for use in sunbeds emit "substantial doses of both UVB and UVA" (Swerdlow and Weinstock, 1998, citing "personal communication from industry sources"). Many of the home and salon devices in the 1980s emitted both UVA and UVB radiation, but current devices emit predominantly UVA (FTC, 1997; Sikes, 1998).

FDA scientists calculated that commonly used fluorescent sunlamps would deliver 0.3 to 1.2 times the annual UVA dose from the sun to a typical tanner requiring 20 sessions at 2 minimal erythematol doses (MED) per session. The common sunlamps would deliver to a frequent tanner (100 sessions at 4 MED/session) 1.2 to 4.7 times the UVA received annually from solar radiation. The frequent tanner would receive 12 times the annual UVA from solar radiation from the recently available high-pressure sunlamps (Miller et al., 1998).

In 1987, an American Academy of Dermatology (AAD) survey found that, although 96% of the U.S. population surveyed knew that sun exposure causes cancer, one-third of the adults responding develop tans. By 1987, the indoor tanning industry was one of the fastest growing in the United States (Sikes, 1998). Surveys of U.S. telephone book Yellow Pages found 11,000 indoor tanning facilities in 1986 and more than 18,000 facilities in 1988. About 11% of women and 6% of men were frequent patrons (Research Studies-SIS, 1989). New York State alone was estimated to have 1300 commercial tanning facilities in 1993 (Lillquist et al., 1994). By 1995, indoor tanning facilities were a \$1 billion industry serving 1 million patrons a day (Guttman, 1995). About 1 to 2 million patrons visit tanning facilities as often as 100 times per year (Sikes, 1998).

A 1990 survey of 1,564 holders of drivers' licenses residing in New York State outside of the New York City area, who were aged 17 to 74 years, were white, and had never had skin cancer, found that 21.5% of the respondents had ever used sun lamps (28.1% among those 16 to 24 years old) but that only 2.3% used sun lamps at least once a month. Ever users were more likely to be women, younger, and never married or divorced or separated (Lillquist et al., 1994). Surveys in the early 1990s of adolescents who had ever used tanning devices have found about twice as many girls as boys among the users (33% vs. 16% and 18.5% vs. 7.4%) (Banks et al., 1992; Mermelstein and Riesenberg, 1992; both cited by Lillquist et al., 1994).

Up to 25 million persons per year in North America are currently estimated to use

sunbeds. Teenagers and young adults are prominent among users. A study of high school students in St. Paul, Minnesota, found that 34% had used commercial sunbeds at least 4 times in the past year. Fifty-nine percent of the users reported some skin injury. A 1995 U.S. survey found that commercial tanning salon patrons included 8% aged 16 to 19 years and 42% aged 20 to 29 years; 71% were female (Hurt and Freeman, undated; cited by Swerdlow and Weinstock, 1998).

Wisconsin dermatologists, ophthalmologists, and emergency room personnel reported treating 372 patients with ocular and/or dermal injuries from artificial tanning devices in a 12-month survey ca. 1990. Of these patients, 53% to 65% were exposed to tanning beds or booths and 17 to 35% were exposed to reflector bulb lamps. In the group of 155 emergency room patients with first or second degree skin burns from artificial tanning, 58% were burned at tanning salons and 37% were burned at home (Garrett, 1990). Although FDA has mandated rules that require that tanning equipment labeling warn about overexposure, skin cancer, possible premature skin aging, and photosensitivity with certain cosmetics and medications, a Public Interest Research Group survey of 100 tanning salons in 8 states and the District of Columbia found 183 tanning devices without the required warnings (Cosmetic Insiders' Report, 1991). Sikes (1998) stated, without attribution, that tanning devices caused 1,800 reported injuries in 1991, mostly in persons aged 15 to 24 years old. A survey of 31 tanning salons in 1989 in the greater Lansing, Michigan, area, population 450,000, found that 87% of the facilities offered their clients "tanning accelerators." Respondents of five establishments stated that their tanning accelerators contained psoralens, but this could not be confirmed (Beyth et al., 1991).

Workers in many occupations, e.g., agricultural, construction, and road work laborers, spend a large component of their work day outdoors. Outdoor workers, therefore, are the largest occupational group exposed to solar UVR. Occupational exposure to artificial UVR occurs in industrial photo processes, principally UV curing of polymer inks, coatings, and circuit board photoresists; sterilization and disinfection; quality assurance in the food industry; medical and dental practices; and welding. Welders are the largest occupational group with artificial UVR exposure. However, only arc welding processes produce significant levels of UVR. UVR from welding operations is produced in broad bands whose intensities depend on factors such as electrode material, discharge current, and gases surrounding the arc (NIOSH, 1972). [OSHA regulations require many protective measures to reduce UVR exposure of workers engaged in or working in the vicinity of arc welding operations.]

A study conducted on laboratory UV lasers such as those used in cornea shaping and coronary angioplasty showed that the relative risk may increase to a level comparable to that of individuals with an outdoor profession (Sternberg et al., 1991).

Applying a mathematical power model based on human data, Lytle et al. (1992) suggested that there is an increased risk of squamous cell carcinoma (SCC) from exposure to UV-emitting fluorescent lamps. The estimates of annual incidence of new SCC, for indoor workers exposed to UV light, indicated that an exposure to typical fluorescent lighting (unfiltered by a clear acrylic prismatic diffuser) may add 3.9% (1.6%-12%) to the potential risk from solar UVR, thus resulting in an induction of an additional 1500 (600-4500) SCC per year in the United States. There is a small increased risk of SCC from exposure to UV-emitting fluorescent lamps, when compared to 110,000 SCC caused by solar exposure.

NIOSH (1972) estimated that 211,000 workers in the manufacturing industries (Standard Industrial Codes [SICs] 19-39) were exposed to UVR; 49,000, in the transportation and communication industries (SICs 40-49); 17,000, in the wholesale, miscellaneous retail, and service stations categories (SICs 50, 59, 55); and 41,000, in the services industries (SICs 70-89).

The sources considered were arc welding, air purifiers, and sanitizers.

## REGULATIONS

The U.S. Food and Drug Administration (FDA) Center for Devices and Radiological Health (CDRH) have promulgated regulations concerning sunlamp products and UV lamps intended for use in sunlamp products. Manufacturers must notify CDRH of product defects and repair and replacement of defects. CDRH issues written notices and warnings in cases of noncompliance. Several performance requirements must be met by sunlamp products (21 CFR 1040.20), including irradiance ratio limits, a timer system, protective eyewear to be worn during product use, compatibility of lamps, and specific labels. The label should include the statement “DANGER—Ultraviolet radiation” and warn of the dangers of exposure and overexposure.

OSHA requires extensive UVR protective measures of employees engaged in or working adjacent to arc welding processes. Arc welding emits broad spectrum UVR. Workers should be protected from the UVR by screening, shields, or goggles. Employees in the vicinity of arc welding and cutting operations should be separated from them by shields, screens, curtains, or goggles. If possible, welders should be enclosed in individual booths. In inert-gas metal-arc welding UVR production is 5 to 30 times more intense than that produced by shielded metal-arc welding. OSHA-required protective measures in shipyard employment and marine terminals include filter lens goggles worn under welding helmets or hand shields and protective clothing that completely covers the skin to prevent UVR burns and other damage (OSHA, 1998a, 1998b, 1998c).

ACGIH (1996) has set various Threshold Limit Values (TLVs) for skin and ocular exposures. TLVs for occupational exposure are determined by these parameters:

1. “For the near UV spectral region (320 to 400 nm), total irradiance incident upon the unprotected eye should not exceed  $1.0 \text{ mW/cm}^2$  for periods greater than  $10^3$  seconds (approximately 16 minutes) and for exposure times less than  $10^3$  seconds should not exceed  $1.0 \text{ J/cm}^2$ .”
2. Unprotected eye or skin exposure to UVR should not exceed  $250 \text{ mJ/cm}^2$  (180 nm) to  $1.0 \times 10^5 \text{ mJ/cm}^2$  (400nm) for an 8-hour period. The TLVs in the wavelength range 235 to 300 nm are 3.0 (at 270 nm) to  $10 \text{ mJ/cm}^2$ .
3. Effective irradiance for broad band sources must be determined by using a weighting formula.
4. “For most white-light sources and all open arcs, the weighting of spectral irradiance between 200 and 315 nm should suffice to determine the effective irradiance. Only specialized UV sources designed to emit UV-A radiation would normally require spectral weighting from 315 to 400 nm.”
5. The permissible ultraviolet radiation exposure for unprotected eye and skin exposure may range from  $0.1 \text{ } \mu\text{W/cm}^2$  (8 hours/day) to  $30000 \text{ } \mu\text{W/cm}^2$  (0.1 sec/day).
6. “All of the preceding TLVs for UV energy apply to sources which subtend an angle less than  $80^\circ$ . Sources which subtend a greater angle need to be measured only over an angle of  $80^\circ$ .”

ACGIH (1996) added that even though conditioned (tanned) individuals may not be any more protected from skin cancer, they can tolerate skin exposure in excess of the TLV without erythral effects. NIOSH criteria for a recommended standard for occupational exposure to UVR are practically identical to those given in ACGIH items 1 and 2 above (NIOSH, 1972).

The Federal Trade Commission (FTC) investigates false, misleading, and deceptive advertising claims about sunlamps and tanning devices (FTC, 1997).

The American Medical Association passed a resolution in December 1994 that called for a ban of the use of suntan parlor equipment for nonmedical purposes. Dermatologists have urged the FDA to take action to discourage use of suntan parlors and suntan beds (Blalock, 1995). Currently, the FDA Center for Devices and Radiological Health and the Centers for Disease Control and Prevention (CDC) encourage avoidance of sunlamps and sunbeds (AAD, 1997). Although 27 states and municipalities had promulgated some regulations on indoor tanning facilities by late 1995, they are seldom enforced (Blalock, 1995). The American Academy of Dermatology's Tanning Parlor Initiative provides a manual giving instructions on petitioning state, regional, and local governments on this issue and examples of regulatory legislation (Dermatology Times, 1990). Regulations are summarized in Volume II, Table A-35.